2D Axisymmetric Temperature Profile Modeling of a Delayed Coking Drum During Pre-Run Warm Up

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Abstract

Delayed Coking is a "bottom of barrel" refining process. A typical feed to this unit is heavy petroleum residue. This process generates a solid petroleum coke and other hydrocarbons with lower boiling point. Due to complex phenomena like foaming, multiphase flow, flow through porous media, chimney effect, and chemical reactions involving heavy oil residue, simulating this process becomes a daunting challenge. Before processing the residue, the coke drums receive nitrogen gas, as a way to check restrictions in the flow lines, and to pre-heat the unit at a given temperature among other safety and process reasons. A 2D axisymmetric stationary model was created in order to simulate this pre-run condition with nitrogen gas, as an attempt to calibrate the model before simulating with an oil residue. The single-phase laminar flow and the heat transfer in fluids modules were used simultaneously. The 3" diameter, 76" long cylindrical SS 316L coke drum was represented by a 1.5" X 76" rectangle. All the fluid properties for nitrogen were obtained from the properties built-into the COMSOL materials library. The pressure set across the coke drum was 15 psig, with an inlet standard flow rate of 2 scfh. For the heat transfer in fluids module, the temperatures values attributed to the boundary and initial conditions were obtained by averaging the experimental data, at 900°F and 15 psig, recorded from the equally distributed internal thermocouples throughout the coke drum length. The boundary condition at z=0" was set to be 900.0°F, while at z=76", 797.2°F. A convective heat flux boundary condition was set at the wall, with the heat transfer coefficient of 44.78 W/m²*K. This was calculated using the constant wall heat flux for Laminar Newtonian flow of 4.364 and the thermal conductivity of stainless steel 316 at 900°F obtained from material built-in the software. For the external temperature, a linear fit with R^2 of 0.9028, obtained from the experimental data, was used. The selected mesh was a physics-controlled mesh, with fine element sizes. The results show that the model predicts a linear trend for the temperature profile (Figure 1) as obtained in the experimental run, it also shows that the model matched the boundary conditions for temperature, without presenting any overshoots. Moreover, due to a vanishingly Reynolds Number of 0.09, the radial temperature across the coke drum is held constant, varying only in the z direction (Figure 2). In addition to that, the temperatures obtained within the model fits well with experimental temperatures (Figure 3).The heat flux calculated by the model (Figure 4) shows a linear trend similar to that observed for the temperature. For the future work, the model will be tested with oil residue, and further implementations, such as multiphase flow, flow through porous media and chemical reactions, will be introduced to the model, in order to obtain other results that closely represent the real process.

Reference

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R.B., Bird et al. Transport Phenomena. 2. ed. New York: John Wiley & Sons, 2007, p. 846-848.

Figures used in the abstract

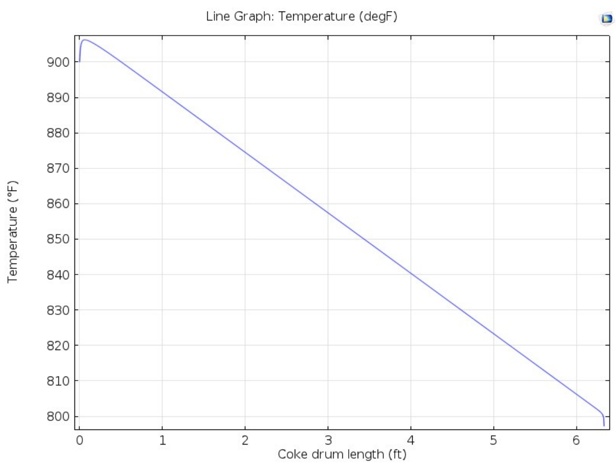

Figure 1: Linear temperature profile of nitrogen along the coke drum in °F.

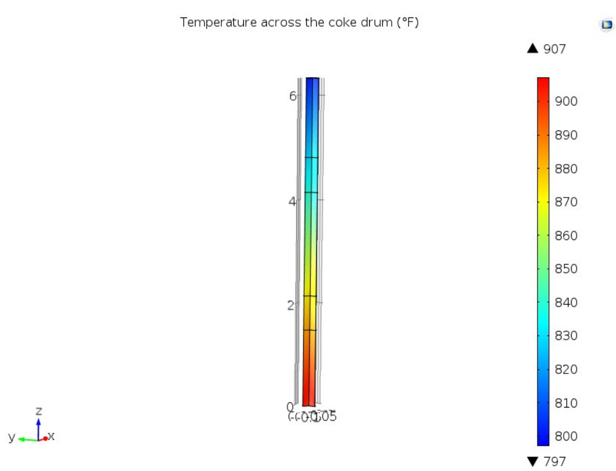

Figure 2: Temperature surface plot of the coke drum, showing only a temperature variation along the axial direction due to a vanishingly Reynolds Number flow.

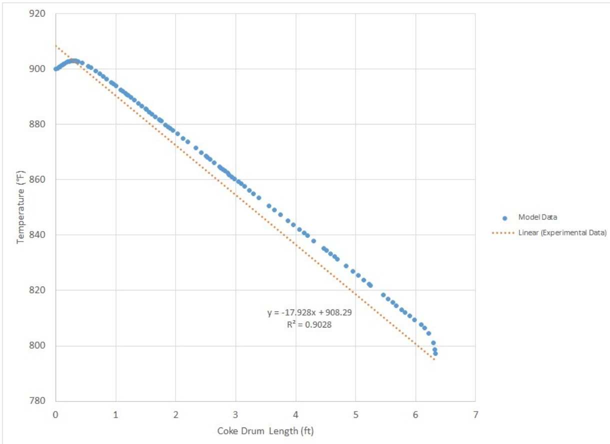

Figure 3: Model data points fit with the linear experimental equation for temperature variation along the axial direction.

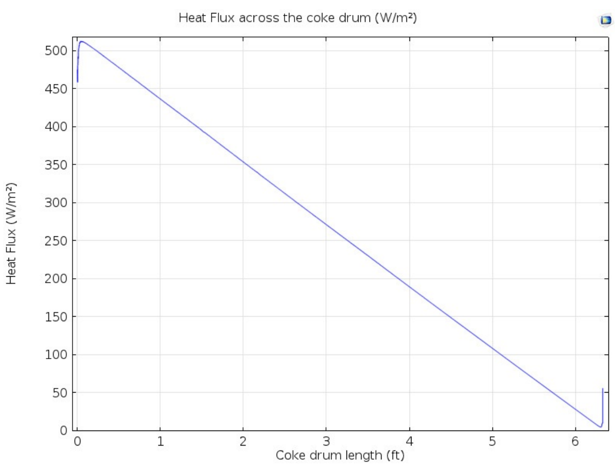

Figure 4: Linear Heat flux profile along the coke drum in W/m².